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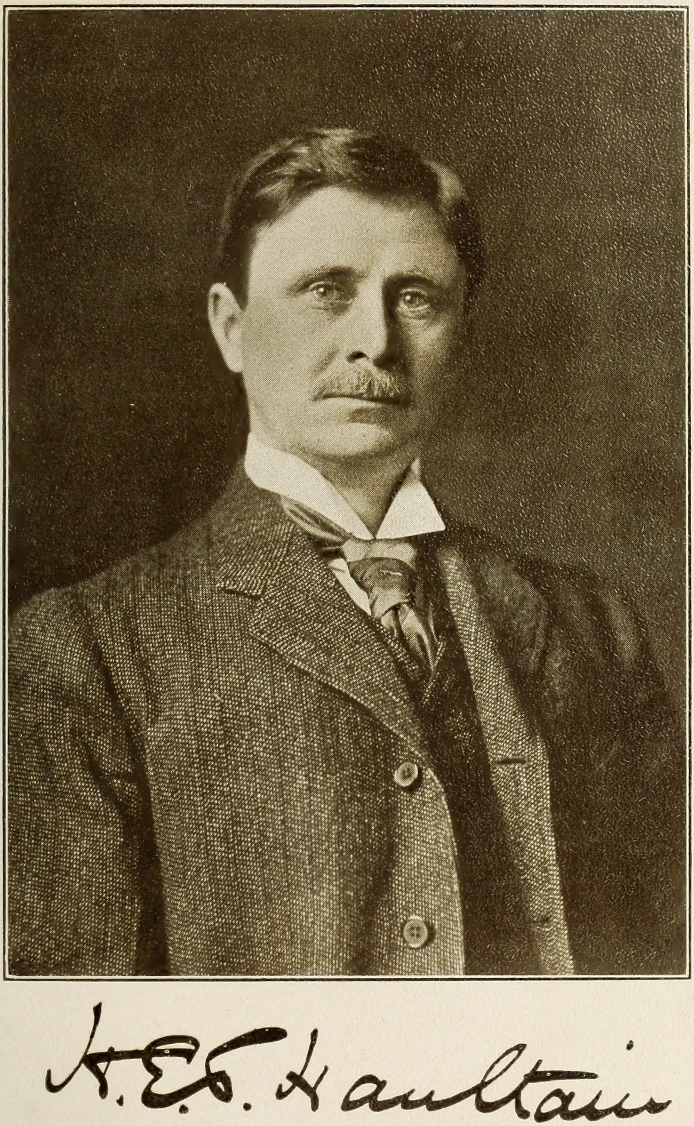

H. E. T. Haultain

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THE YOUNG GRADUATE AND THE PROFESSION OF MINING ENGINEERING*

H. E. T. HAULTAIN, C.E., Mem. Inst. Min. Met.**

Both in my own experience and in my observation of young graduates from engineering schools in all parts of the world, I have found a general ignorance of the profession as a whole, generally coupled with a very much distorted view of the young graduate's position in, and relation to, his profession. This is probably to a very large extent unavoidable, but it has always seemed to me a very important point, and I should strongly like to see a series of lectures on the subject embodied in the general curriculum of the school. Doubtless very much of such knowledge must be personally and painfully learned by experience, but a very valuable skeleton of information could be built up in the lecture room. In the short time at my disposal, I will attempt an outline of the profession of mining engineering as I in my limited experience have found it, and attempt to deal with some of the more prominent difficulties that will be encountered in the early days of the Young Engineer's career.

Kipling says:

> "When the waters were dried an' the earth did appear,
> The Lord, He created the Engineer."

And, from the first, the mining engineer must have been a man of prime importance in his class. As time went on, and all structues depended more and more, either in their fashioning or in their material, upon the supply of metals, so would the importance of the miner become greater. In France and Germany this is recognized, and mining engineering ranks ahead of all other branches of engineering, but in our English-speaking communities it is not officially accorded the same recognition, and possibly the miner is often considered rough and unfinished in his methods, a pioneer occupied in coping with nature in the rough and lagging far behind the polish and finish of the scientific engineering of the cities. It is true he is a pioneer and that he deals with the forces of nature in her crudest and roughest forms, but he does it with a wider range of scientific knowledge than that possessed by any of his engineering brothers. He needs and he makes use of the specialized knowledge of all other branches of engineering in addition to such that is peculiarly his own.

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*An address delivered before the Engineering Society in 1902. This will be followed by an article, "The Mining Engineer and his Relation to the Public," with particular reference to Ontario.

**See Biography in Section 2, page 3.

The profession of mining engineering embodies very much more than any one man's mind could possibly encompass, and there is a limitless number of subdivisions or combinations of subdivisions for the specialist in which to bury himself.

In general, mining engineers are divided into two main classes, viz., Mining Engineers and Metallurgical Engineers. Under this classification in its closest sense, the mining engineer has to do with the getting of ore to the point where it lies in a broken state at the surface, and the metallurgical engineer carries on the work from this point until the metals are finally extracted from the ore. But as a general rule the metallurgical engineer's work is confined to smelting operations, while the processes of mechanical concentration of ores, and even the leaching and lixiviation processes are in the hands of the mining engineer in charge of the other mining work. The reason of this is to be found in the fact that as a rule the mechanical concentration and lixiviation of ores is carried on at the mines under the one management; while smelting is generally done at some central point at a distance from the mining operations. The department of smelting I must leave out of consideration, and trust some other graduate will take up this very important branch.

Of mining engineers proper, there is a rough classification that will divide them into two classes: the engineers connected with the large permanent mining centres, usually coal and iron; and those connected with the general mining industry scattered all over the world. It is with the work of the latter class that my experience has been and it is with them that I will deal. This class of mining engineers is again subdivided into two main classes—the consulting engineer and the managing engineer, and the thoroughly competent consulting engineer will have passed through the stage of managing engineer. The work of the consulting engineer can be divided into two main divisions—reporting on the value of properties and reporting on the management of properties. The term managing engineer would embody in its general sense all the engineers resident about a mine, and would include assayers, chemists, surveyors, mechanical engineers, electricians and those engineers skilled in concentration and lixiviation processes.

The prominent consulting engineer would have his headquarters at some commercial centre—London being the particular home of this class—and he might or might not have assistants or partners in parts of the world nearer to the mining centres. A large part of his work—perhaps his sole work—would be the examining of and reporting on, the value of mining properties in various parts of the world. This is of course most important work and is correspondingly paid for. In this work experience and judgment, built upon a foundation of wide scientific knowledge, coupled with a well balanced commercial sense and the necessarily ever present disinterested integrity, are the main requirements. It is a position of the utmost commercial responsibility, a single report often controlling the investment of millions. The keynote of success is of course Reputation, and before a man could expect to succeed at this work, he must have built up a reputation, and have made friends. The fees for this kind of work are high. Among prominent London engineers the fee for a report of any consequence would not often be under $5,000.

Consulting engineers located in either commercial or mining centres also undertake the reporting on the management of mines. They may visit the mine at intervals, or they may simply base their reports and advice on the information, accounts, etc., supplied to the company by the mine manager; and their advice might extend to the supplying of detailed plans for development or for machinery. Consulting engineers in this capacity are frequently engaged by London companies owning mines abroad.

The position of consulting engineer, with a reputation, able practically to choose his own work, travelling in many parts of the world, returning always to his headquarters, and receiving most substantial fees, is a most enviable one, and is one looked forward to as a natural consequence of years of successful work in the field.

But it is to the position of managing engineer, and the steps subordinate to that position that I would more particularly draw your attention. Perhaps I could not do better than outline the duties and responsibilities in an actual case.

Take the case of the manager of an English Company owning mining territory in Africa. They have one mine partially developed and several prospects giving more or less promise of good values. This Company is managed in London by a board of directors—non-technical men—with a chairman at their head. This Board will meet once a month, or once a fortnight, and will outline the general policy of the Company. The details as far as the London end is concerned are in the hands of the chairman, who relegates them largely to the secretary, who corresponds with the manager in Africa. The manager will have a wholesale power of attorney to do anything and everything in Africa, and will be answerable for all his actions directly to the Board. He will have an agreement or engagement as manager, terminable as a rule by six months notice on either side. He must of necessity have had the full confidence of the

Board before he was apppointed, and must retain this to the full or his position will become untenable. The Board will be completely at the mercy of the manager—their only information being what he chooses to give them in his letters and reports, together with that obtained through an annual visit of a director or a consulting engineer. The manager in turn will be very much at the mercy of the misunderstandings and disappointments of the Board, and nothing but full confidence can keep things running. The keeping of the Board well and judiciously supplied with information is perhaps one of the most important functions of the manager.

Coming nearer to his work, we find him in charge of an isolated community twenty miles or more from a settlement—100 miles from a railway—with slow-going ox-wagons as the only means of freight transport.

First and foremost he must examine his ore deposits and then with all the knowledge that he possesses of geology and minerology, he must form some opinion of their probable value and outline a method of development. With his already partially developed ore deposit, all his past experience of the costs of mining and ore treatment, together with all the information he can obtain in a raw country concerning labor, power, fuel, transportation and markets, will leave him in no high degree of certainty as to probable profits. He has to study the resources of the country, and to design his plant accordingly. He is alone, single-handed, and up against the real thing. And he has to organize in a bare wilderness a large and complex business. While keeping his mind keenly on the deep scientific problems of the various and varying ore deposits, on the problems of haulage, timbering and ore treatment, he has to arrange for the establishing of his camp, the housing of his men and animals, the purchase of innumerable supplies and transportation over difficult country. He has to procure, and very often to a large extent must be prepared to train, a most varied gang of workmen, skilled and unskilled, in all branches of labour. He has to control a most mixed lot of the roughest class of men, both white and black ; at all times he must preserve his personal influence and tone. He is the single-handed autocrat of an isolated community, with nothing to maintain his authority but his own personality. He is spending large sums of money, and spending it in innumerable ways that are difficult to trace and check. On all sides are men trying to get the best of him in every proposition, and he must have the business side—the commercial side—of his work organized to a degree unthought of in many establishments nearer the centres of civilization.

While organizing and personally controlling these varied complexities, he must ever keep a clear mind for the constant, careful and well balanced study of the intricate scientific problems of his work.

Let us consider some of these engineering problems.

In the first place his ore bodies differ in many respects from any he has had any previous knowledge of—no two ore bodies are the same. Nothing but experience—wide and varied experience—founded on scientific training, is going to save him in the solution of the problems involved in the exploration of his ore bodies.

He has one ore body so far opened up that sufficient values are in sight to justify the installation of machinery on a large scale for the breaking, mining and treating of his ore. Upon all the intricate details I cannot touch, but let us look at some of the main problems involved.

The first problem of mining his ore and protecting his underground workings is one depending almost entirely upon judgment and foresight based on experience, and is one that no amount of training or reading can solve for him. In any case he must work tentatively—must feel his way. That probably is the keynote of all underground work—certainly of all the early stages. It is impossible to see far ahead, and one must feel his way foot by foot—planning tomorrow's work by today's results.

But the planning of the ultimate development which must soon be taken in hand is a large problem involving work spread over many years, and the general skeleton of the plan must be laid out and undertaken at once. Upon the position of the main working shaft or tunnel the position of his surface works will to a large extent depend. Into this problem must enter the problems of pumping, ventilation and haulage, and much calculation and well balanced judgment are required for a satisfactory solution. The problem involves not only a very large sum in itself, but will always very seriously affect the working costs.

Inseparable from this problem is the question of power. The case I have in view has practically unlimited water power five miles away, so that the question of power does not affect the hoisting question; and it is found that for the first few years the most satisfactory course is the running of a low level tunnel which will give several years ore supplies above it, and which will always be the main working tunnel.

The next problem is the treatment of the ore, and though the manager ought to be capable of dealing with this problem himself, he may call in the assistance of a consulting specialist.

And here comes in a very nice point:

It is of course out of the question that our mine manager should know everything, or that he should know as much of detail as a specialist in any branch, and very naturally the average business man will say: Here is an isolated problem, let it be solved by the specialist.

In the large mining centres are to be found consulting engineers, who are disinterested specialists in milling and lixiviation processes, and who make a business of such problems. They often are called upon to supply complete plans.

In the first place, there is one statement that will hold under all circumstances:—There is no isolated problem connected with any mine. The mine and everything connected with it is one vast complex machine, with all its parts and details interdependent, and smooth running—successful running—depends on the balance between all its parts, and upon their perfect interworking. This can only be achieved in one mind. There can only be one controlling hand, and though it is not necessary for the manager to design all the details, he must fully grasp the essentials of every department. He must be responsible for everything.

If outside consulting advice is called in, it must be in consultation with the manager, and if the manager is incapable of dealing with the subject, a most dangerous element of failure is at once introduced. This is a most essential element of mine management, and I will refer to it later on.

If a thorough professional consulting engineer with a reputation is called in to settle the problem of ore treatment, he may be prepared to deal with it in its entirety, in which case he would go carefully into all the conditions surrounding the problem from the ore deposit to the market, and would do this in close consultation with the manager, whom also he would carefully consider as an important condition. Then after designing the plant he would to a certain extent supervise construction, and on its completion would personally attend to the early stages of its operation. For an ore treatment plant is not like a small steam engine which will run when supplied with steam. Even after most careful and capable designing, there will have to be much adjusting of its method of operations before the best results are obtainable, and this adjusting must be done by a capable and responsible head.

If the specialist's connection ceases on the delivery of the plans, the manager's responsibility will only then commence, and if there be any failure in results the manager will blame the design and the designer will blame the method of operation, and the company will be in the position of the man trying to sit on two chairs. This is one of the commonest causes of failure and trouble in mining, and every mining man can point to many incidents of this kind.

In the case I have described the specialist's fee would be enormous—probably much larger than the manager's annual salary.

Most frequently it would not be possible to obtain the services of a distinguished specialist and recourse is often had to the manufacturers of mining machinery. They call themselves specialists in such matters and very often are so, and have much experience and data at their command, but we then have the anomalous position of the consulting engineer and the contractor being one and the same person. It is surprising how frequently this is the case, and it is not surprising that this is most frequently a cause of disaster.

The manufacturer can never be a disinterested party. Conditions do not permit him to make a thorough examination of all the conditions. He will tell you what machinery to put in; it will be his own, and there will be as much as possible of it; it will be good machinery, and he will guarantee the smooth running of individual machines, but he will not guarantee the results. And he will have many excuses to show that the blame of failure is not attachable to him. He will tell you that the ore treated in the mill differs from the sample sent him; that the construction was poor and the operation is worse. You cannot pin down the manufacturer to results—he is too old a bird at the game.

What then is the manager to do?

He ought to be capable of designing his own plant. If he feels doubt about it, let him engage a man who has knowledge of such matters, engage him as an assistant—as a head of a department—and let this man experiment on a laboratory scale in co-operation with the manager.

After the manager, with or without outside aid, has decided that his ore is a free milling ore requiring a subsequent treatment of tailings by cyanide, and has decided on the general main idea of his plant, he can safely go to the manufacturer for his machinery, trusting largely to him for all details—for the details are the work of a mechanical engineer, and in this department the manufacturer is the highest specialist.

The first plant will doubtless be a small one, designed with a view to further increase, and also with a view of permitting considerable experimenting.

What I have said in regard to the ore treatment plant also holds good with the tramway from the mine to the mill, and with the water power plant, and with the electric transmission plant, with of course some modifications.

Aerial tramways come nearer to being isolated problems than does any other part of the plant, and they are very frequently given over to contractors, who guarantee to erect the tramway and run it for a short time. To a certain extent the tramway can be looked upon as an isolated machine of the nature of a steam engine. But again to make the contractor and the consulting engineer the same person, even in so simple a matter as a tramway, tends to an unnecessary waste of money and consists in paying to a contractor very much more than what is already paid to the manager or his staff for the same work.

In the case of electric machinery—electricity is perhaps somewhat removed from the mining engineer, but is daily becoming less so, and though the mining engineer would certainly never attempt to design his dynamos, he certainly ought to know enough to decide whether he wanted direct current or alternating machinery, and to be able rationally to check over the electrician's figures as to line loss, etc., etc.

To sum up this question of machinery, the manager should be thoroughly conversant with all the standard types of machinery of all the prominent manufacturers that might possibly be of use in mining work, and this includes practically everything except heavy ordnance and marine engines. With the detailed design of this machinery he need not unduly burden himself beyond understanding the why and the wherefore of every part. The manufacturer can be depended on for excellence of detail. Thereon depends his existence.

The erection of his plant is an all-important part of the manager's work or of a most trusted assistant. To let this by contracts generally ends in disaster unless most competent and keen watch is kept on the contractor. Generally speaking, in all mining construction, it is more satisfactory and more economical to watch over a good foreman than to check a contractor. The contractor, like the Indian, will be bad if he can be.

The operation of the plant will be the work of the heads of departments, always under the personal eye of the manager.

This is a bare skeleton of the work of the mine. It is filled in with an interesting network of details of every kind, from the niceties of subtle chemical investigation to the handling of a drunken mob, and through it all must run side by side the deepest scientific thought and the most cold-blooded business methods, tempered always by the truest disinterested professional tone.

The manager will have to assist him at his work, besides his own personal assistant, several heads of departments—a commercial superintendent in charge of the buying and of the books and the commercial side of the business generally; a surveyor, an assayer, superintendents or head foremen of mine, mill and cyanide plant, a master mechanic, and foremen of the various subdepartments, and with these the successful manager will keep in very close, intimate touch.

There is another phase of the manager's work that I have not yet touched upon—a department in which he remains alone.

The mine is the property of a company, and the public pay very much more attention to the shares than they do to the mine, and the majority of shareholders expect to make very much more out of the fluctuation in the price of shares than they do out of the mine. There is a constant active buying and selling of shares. Now the manager's regular reports to his Board can very materially affect the price of shares, and his plans of operations do also very materially affect the price of shares; discoveries will be made in the mine that will make enormous differences in the value of the stock. In very many ways the manager has a very large control over the price of the stock, and if there be any deviation on his part from strict honesty, from the true professional spirit of disinterestedness, he may be in a position to make much money for himself or his friends. Here is a wide open temptation—a temptation so coarse and glaring—so palpable—that it will in general be easily avoided, but it has also its more subtle aspects, and the only protection a man has lies in the inherent honesty, the professional spirit and the tone of the true engineer.

This is an outline of the position of a manager of by no means large property, and may be taken as a fair general example.

As an example of the extent to which the business of mine management may grow, I would cite the case of The Consolidated Gold Fields of South Africa. In 1897, in their engineering offices in Johannesburg, they had fifteen draughtsmen in the surveying department, and seventeen more in the general department. Their chief engineer drew a salary of $60,000 a year, their chief mechanical engineer drew $25,000, and so on. Of course this office did all the engineering work for a large group of mines.

But it is the smaller propositions that tax the resources of the mining engineer most severely, for in these cases he must himself control every department, and must carry out works that in larger concerns would be in the hands of heads of departments in themselves specialists capable of carrying responsibility.

In an examination of the duties of mine manager, as I have outlined, what do we find as the more prominent points? I think that we shall find that the most important point of all is confidence—mutual confidence between the directors and the manager. To obtain this the manager must be a man of experience—a man with a record—a man who has made friends. The next point of importance is the fact that the whole concern, first, last and all the time, is a business proposition undertaken with the sole and only purpose of making money, and as far as our engineer is concerned, making money legitimately, though—and this is a point ever to be remembered by the young graduate—there are always those seeking to make money illegitimately. The whole concern in every department must be organized on a commercial basis. The third point of importance is the essentially scientific character of all the problems involved in the finding, winning and treating of the ore. In the young graduate's technical course, his whole time and energies being occupied with this latter point, he is apt to lose sight almost altogether of the other two. But these three points are as inseparable as the three dimensions of space, and any proposition founded on two only will be a failure.

Of course there is an exception to this rule—the factor known as luck may upset all rational conceptions.

Besides these three fundamental points there are others of nearly equal importance. All mining work is new work; every problem is a new one, differing in many respects from the engineer's previous experience; every problem is complex, involving a large number of facts and conditions often very obscure. The engineer must be a man of varied experience, not only conversant with a wide range of scientific knowledge, but with a very wide range of actual experience. He must be essentially quick witted and he must have a lively technical imagination, ever ready to imagine new combinations and possibilities. But his temperament and technical character must be strong enough to allow this imagination full play, without it carrying him off his feet into a wilderness of conjecture.

He must be physically strong—able to live anywhere and eat anything; he must ever be ready to pack his blankets and his scientific knowledge on his own back.

He must be a professional man in the fullest sense of the term. He must have tone; I cannot define tone, it marks quality, or shall I say quality marks tone. And tone is as unassailable as it is hard to define. From the first step to the last the mining engineer is surrounded by temptations of every kind; every tendency within him will have free opportunity to pull him towards disaster. From the start he is away from the influence of custom and social ties, and he who has never been absolutely free from these influences can have little conception of the extent of their controlling power. But the temptations arising from avarice and ambition are the most continually and persistently present. And these temptations are often of the subtlest kind—most frequently not having even the appearances of temptation, and this is a phase of his work in which the engineer stands alone—a game in which he must play a lone hand.

Disinterestedness is the foundation and skeleton framework of the whole structure of the professional man. If he is not disinterested he is nothing. He is an employee and his interests always must be on behalf of his employer. This explains how the mine manager can be a business man and still a professional man. He is carrying on business for another and he can carry it on only in the cleanest and straightest of business methods.

Another thing to be observed in the work of our mine manager is that he has more to do with human nature than with any of the other forces of nature. He has to deal with his directors on one hand, and with his employees with the other. He has to deal continually with the cleverest scoundrels and rogues of all classes and kinds. He has to depend on his judgment of character in black, red, yellow and white.

Well, gentlemen, have I painted an impossible picture for you? I have outlined the main skeleton frame of a possible structure—a structure for which there is an enormous demand; the completion of the edifice depends upon the individual.

So much for what there is in front of us. Let us now consider our first steps.

The young graduate, despite his hard work and scientific attainments, is, as an engineer, well nigh as useless as the newborn babe. I know you will not believe this—it is not compatible with your years and your efforts—it is probably just as well that you don't believe it, but it is one of the first important things that you must learn in the outside world.

How is this so? Thus: the young graduate has had no experience (I know there are exceptions), consequently can have no judgment, and therefore is absolutely incapable of responsible initiative.

Many people will tell me I am entirely wrong—that the young graduate is full to overflowing with judgment—that he will judge anything or anybody, and as for initiative, he has the nerve and the supreme self-confidence to tackle any proposition—to initiate anything. Exactly—that emphasises what I mean—he has no judgment—that is, no judgment that can be depended upon.

In England they put the embryo engineer in an incubator—that is—he is articled as a pupil for one, two or more years to an engineer of standing and experience, and for this privilege he will pay as much as $1,000 a year, and will receive no pay of any kind in return for his work. With this idea I would be wholly in accord, if the conditions in the colonies permitted it. I would not advise for a colonial mining graduate an articled pupilage in England; but if a western mining engineer would take him, he could not possibly do better. But out here the conditions are different, and we have to face conditions as we find them.

In the first place, many of our technical graduates have not the means to pay any pupilage fees, nor even to give their services and time for nothing; they must earn soon after graduation. And again I do not think you could persuade any mining engineer in active work on this continent to accept pupilage fees or to have about him a pupil working for nothing.

The young graduate must earn money, and it is a function of the technical school to leave him in a position to do this, and there are two or perhaps three or even four branches of work in which the technical schools can turn out commercially useful men. I refer to assaying and surveying, and to a certain extent, draughting.

The school can—if it chooses—turn out men who could take hold of the position of assayer or of surveyor at any small mine, or who would make excellent assistants on a large property. These positions require practically no judgment or initiative, and the main difference between the work at the school and the work at the mine consists in the rapidity that is required in commercial work, and a certain ability to make shift with the anything but ideal conditions and appliances that one may be up against. If to a smooth working knowledge of assaying and surveying, the young graduate has added an active knowledge of bookkeeping and cost-keeping, he has three strings to his bow that will earn him a living in any active mining camp.

It is a common saying in the West that if you cannot get one job you should take two, by which is meant that you may often be able to get a job as an assayer and bookkeeper combined where you could get nothing if you applied for either singly. My advice to any technical school would be—make bookkeeping and cost-keeping and the commercial organization of engineering business, an important part of your curriculum. My advice to any student of a school where this is not part of the curriculum is, to take steps to make a special study of these subjects at the earliest possible opportunity.

The obtaining of a position as assayer or surveyor, and, from that position, studying the actual working conditions of a mine, to be ready for further advancement in your profession, is the orthodox method.

The surveyor has the better opportunity— he is here, there and everywhere on the property—mixed with everybody and sees everything that is going on, and will be more naturally given the position of acting manager or assistant manager.

However, before going any further, let us consider more fully the functions of the first few years after graduation. The first function doubtless is the earning of a living, and the orthodox way of doing this I have outlined. But if you stop at that, you will never be an engineer. The main function is to get experience—wide, varied experience—of everything you will need in after years. Another function is to make professional friends, but the main point is experience.

In your S. P. S. course you have had a most excellent training. You have been trained to think—to reason—to read and to a certain extent to observe—you have been trained to ask the question " why" and to make an effort to rationally answer that question. You have learnt much about the physical laws underlying all engineering problems. The excavations have been dug and a very substantial foundation has been laid for a very elaborate superstructure; and further than this, the skeleton steel frame work has been in part erected; and even still further, if the material for further erection has not been gathered, the method of obtaining it has at least been indicated. You can live in the cellar if you like, but that will never make a house of it—you will never be an engineer. You must build on the foundation. You must fill in the skeleton frame work —you must erect extensions to your frame work—this you must do alone. Nobody else can do it for you. The elaborating of the structure is by personal experience. In my student days Prof. Galbraith advised us to devote the first ten years after graduating to the sole function of gaining a varied experience. I think this most excellent advice. No matter what position you hold you will be gaining experience, and to gain a varied experience you must not stay too long in one position. But you must not trust to haphazard luck in the positions you get. There are several points to be remembered. In the first place in your early days you can do things that later on in your professional life, you could not do. For instance, on graduating you could work as a mucker or common laborer underground—or you might innocently be employed by some notoriously corrupt men or companies. In neither case would your reputation suffer, and you would be the gainer by some valuable knowledge.

The most prominent feature of mining work in all parts of the world (and in Canada and Ontario have we had most scandalous examples of it) is the extreme corruption, crookedness and dishonesty that frequently accompanies it. This exists to a degree beyond all conception by those who have not actually seen it. If you keep this fact in view and remain always ready to quit a job when it looks dirty, you can in your early years take pretty nearly anything you can get, but later on you must be more careful what you do. Then the main point would be to get near good men, near good companies and successful concerns.

In your early years there are several very unorthodox things that I would advise. In all mining work the biggest item is for labor, and there is no other item of expenditure in which money may be lost or saved to the same extent. The human machine is not only the most used, but it is the most complex, and to be a successful mining man you must understand your workman. The best place to study your workingman is alongside of him. I strongly advise every young mining graduate to work as a mucker or trammer underground in some fairly large mine. To do this properly you must do it thoroughly and drop all your engineering business, and your diploma and all that, and get into dirty overalls and get your job from the foreman and sleep in the bunk-house and keep away from the office. This I know is often advised, and in Cornwall and Freiberg there are regular practical courses underground where the students play more or less seriously at work, and learn after a fashion to swing a hammer and frame a set. Candidly I don't think much of that—I do not see that such work is of very much use, and in those practical courses you don't learn anything of the men—you don't get round to their point of view. This to my mind is the essential point, and my advice is to get a mucker's job and hold it at least over one pay day and over several if you can. It will hurt and it will be hard, but it will be worth it.

Again, if you have any inclination towards carpenter's work or machine fitting or any opportunity to follow up such work, I say by all means do so. I know of no better qualification for a young man seeking mining experience than a knowledge of machine fitting. There is no part of a mine free from machinery, and the fitter is wanted everywhere and gets a job more easily than any other class of skilled or semi-skilled workman; while a carpenter can often get a job on mill construction or the like that will give him an insight into construction that he could get in no other way. These are not short cuts to success or by-paths—they are stepping stones and most valuable ones at that. I would strongly advise the mining student to spend at least one of his summers in a machine shop or in a carpenter's shop. I would consider this better than a summer spent in an assay office, on survey, or in a mine.

The next question is as to where the young graduate is to go on graduation. Into the question of a post-graduate course I cannot go beyond saying that I am in favor of a post-graduate course, and would still recommend Freiberg despite all the advances made by technical schools on this continent.

After the completion of his technical course he should go to some active mining camp, and I certainly would choose the Western States. I am enthusiastically a Canadian, but I do not advise the young mining engineer to remain in Canada. He should go to an older mining country for his experience, and the United States—the Western States—has trained and still is training the world's most prominent engineers. And when you go west leave your diploma behind you, also your testimonials and recommendations. You will be looking only for subordinate positions, and for these positions men will size you up by looking at you and will discharge you as casually as they engage you. Never be afraid of quitting a job. It is no disgrace—very often it is not a bad thing to be discharged. A willingness to turn your hand to anything and everything that comes your way and do it with your best effort, are traits that will help you more than others. It will be several years before you get to what your heart pines for—that is real engineering work—but you must not neglect it for that reason; your eyes must always be open to everything about you, and you must read everything you can lay your hands on—technical magazines and catalogues in particular.

You will probably find the life a hard one, full of painful physical effort—full of misunderstandings and disappointments. Hope will be long deferred. Your scientific attainments will seem lost—swallowed up by chance and the force of circumstances. You will think you are losing all your finer feelings—your social niceties; the latest operas and plays will hardly be known by name to you and the popular airs will be three years old when they reach you. Life will be anything but a soft snap and your only consolation will often be: "Well, it's good experience, and anyway, it's all in the day's work!" You will find that you will have to give up very much, if not all that went to make life pleasant, and you will get in return—if you are lucky—work—and in many years—if you are lucky—well paid work.

But you will see—and if your eyes are open, life will be very full—you will play your own game with a freedom and a scope unknown in any other profession. You will have opportunities to carry your tendencies to the full. You will be with men and you will work with men, and the conditions and surroundings will be such as to bring out, in full prominence, the characters good and bad of men. Veneer and polish will be absent, and if you are a lover of men you will love your life. If you want an easy life leave mining alone. If you are not a tramp and want everything settled—if you are contemplating early marriage—don't go in for mining, for you will have to live and work where it would not be fair to take her.

PRELIMINARY STUDIES IN CONNECTION WITH THE DEVELOPMENT OF HYDRAULIC POWER

H. G. ACRES, '03

It is not within the scope of this article to fully discuss such a subject as this, as every hydraulic problem involves features peculiar to itself, which require special study and treatment. For this reason it will be necessary to make certain assumptions and follow out a line of reasoning based upon them.

Assuming, therefore, the existence of a stream upon which, at one or more points, power development is structurally and economically feasible, the first point to note is that the very fact of development being economically feasible implies the existence of a market for the power output, or at least the certainty of establishing one within a reasonable time. So that before the hydraulic features of the problem are considered in detail, the commercial possibilities must first be studied with a view to ascertaining whether or not there is sufficient inducement offered to proceed with development.

The character of the market available to any source of power will vary widely with its geographical situation. In some localities the power output of the plant will be disposed of at the turbine-shaft, as is generally the case in the manufacture of pulp, lumber, flour, etc. In other localities it may be necessary to transform the mechanical output into electrical energy to meet the requirements of the market.

In the first case the problem is a comparatively simple one, it being simply necessary, in the majority of cases, to instal sufficient hydraulic capacity to meet a steady demand for power, the amount of which can be very closely estimated. In the second case, however, owing to the wide range of industrial uses to which hydraulic energy can be electrically applied, the question becomes much more complex, and for its proper study requires careful investigation and the exercise of conservative judgment, for the conclusions arrived at will have an important bearing upon the general design and lay-out of the plant and perhaps also upon its location, where more than one site is available.

The topographical features of the power site and the conditions of flow will of course be the main consideration in connection with the method of development, and will determine the limiting capacity. Apart from this, in so far, at least, as the installed capacity is concerned, deductions derived from a study of the market will be the controlling factor. It is to be noted in this connection that estimates of required capacity should not be based upon the lump sum of all contracts entered into or in sight, but upon estimates derived from a classification of these contracts according to the hours of service called for. It will then be possible to arrive at an approximation of the installed capacity required to handle the peak load, this being the value which obtains when the simultaneous demands of the power-users become a maximum.

An estimate of the average load can also be approximated, and from this an idea can be formed as to the proper capacity of the individual units to be installed, with a view to handling the variations of load with a maximum of efficiency.

This may be summed up by stating that for a maximum of operating efficiency, the lay-out of the plant and the individual capacity of the units will depend upon the load-factor, which is the ratio between the maximum and the average load; thus in the general case a small load-factor will call for individual units of small capacity, and as the load-factor approaches unity a smaller number of units having larger capacity will give the best economy. It is to be noted in the latter case, however, that where continuity of service is of first importance, the concentration of capacity may make the installation of a spare unit necessary.

A general investigation having established the fact that a suitable market is available, the hydraulic features of the problem may then be taken up in detail. The first point to be considered in this connection is the amount of water available, and a reconnaissance survey should be made of the watershed from which the supply is drawn. In this way information will be obtained as to the area of the watershed, the gradient of the stream, and general topographical features, such as the nature of the soil, amount of wooded and cultivated land, and the number and extent of lakes, marshes, etc.

An approximation close enough for practical purposes can usually be arrived at with reference to the area of the watershed from existing maps of the district. In Canada the Geological Survey maps answer very well, especially in the unsurveyed districts, as they are fairly accurate and contain a considerable amount of detail. The standard topographical maps published at Ottawa under the direction of the Dominion Geographer are still better, but these maps so far embrace a comparatively small area. Both classes of maps are plotted to a four-mile scale and notes can conveniently be made upon them in the field.

During reconnaissance particular attention should be paid to the possibilities of artificial storage along, or at the head-waters of the stream. Owing to the fact that the quantity of continuous twenty-four hour power available per foot of head depends upon the amount of water discharged under conditions of minimum flow, any steady increment which can be added to the minimum flow will increase the continuous twenty-four hour capacity in the direct proportion; and, if the maximum available head at the power-site has been utilized, and the market has absorbed the continuous capacity derived from minimum flow, the only way of "hydraulicly" meeting any further demand for continuous power is to augment in some way the natural low-water flow. This is generally accomplished by improving the natural storage facilities of the watershed, and, as before stated this is one of the most important points upon which information is to be obtained during reconnaissance.

The field work in this connection consists in collecting information as to the area of the various lakes and other adaptable storage basins above the site of development. Lake outlets should be carefully examined with a view to obtaining suitable cross-sections for damming, the topographical advantages of these locations being offset against the possible liability to land damages resulting from the construction of dams. If the watershed contains much cultivated land and the scheme of development is at all extensive or elaborate, all these storage basins should be traversed, dam-sites cross-sectioned and flood contours established. This will furnish sufficient information to establish the location, method of construction and extent of storage works and to admit the computation of flooded areas. To supplement this, data should also be obtained from the nearest weather station concerning the value of the mean annual precipitation, snow being reduced to water, and also the value of the mean annual temperature. It is well to get these records for as many years back as they extend. Empirical formulae giving a value for annual evaporation have been derived which involve the values of mean annual precipitation and temperature, but they are not safely applicable in a general way, owing to the fact that the constants involved have been based upon local data. Generally all that can be done is to obtain from the yearly records the minimum value of mean annual precipitation. This value, used in conjunction with the area, will give the probable minimum value of the total annual precipitation over the watershed.

From data collected during reconnaissance it will now be possible to assume a value for the "run-off" factor by which is meant the percentage of total annual precipitation which will be available for power purposes after allowance has been made for dissipation by evaporation, seepage, and the requirements of vegetation. This quantity varies widely with the locality and depends largely upon climatic conditions but also upon the topographical features of the watershed and the gradient of the stream; thus, in a watershed containing a large proportion of cleared and cultivated land with small lake areas and steep stream gradient, maximum values of the run-off factor would obtain, owing to the fact that a large portion of the precipitation would be carried off by freshets, while it would tend toward a minimum in the case of a sluggish stream draining a watershed containing a large proportion of open hard-wood forest and large lake area, these conditions tending toward a maximum of evaporation and seepage, and absorption by vegetation. The value of this run-off factor is generally from 30 to 60 per cent., but it often runs below 30 and sometimes reaches a value of 80 per cent. in the case of short mountain streams.

In Ontario the rivers tributary to the Lower Lakes will probably deliver 25 to 50 per cent. of annual precipitation, while those tributary to Lake Huron and Lake Superior and throughout New Ontario generally will deliver 40 to 60 per cent., some of the shorter and more turbulent rivers probably running as high as 70 per cent. The higher values are assigned to the northern rivers chiefly because their watersheds are largely covered by evergreen forest, which protects the ground surface from the sun and wind.

It should be noted that this exceedingly approximate method of estimating run-off is permissable only when it is impossible to obtain more exact data or in cases where the minimum natural flow is known to be sufficient to abundantly cover all estimates of market requirement. This applies only to rivers like the St. Lawrence and the Niagara.

In most cases, however, although such an estimate may be made valuable by the exercise of experienced judgment, it is necessary to supplement it with data derived from direct and frequent measurements of discharge. Too much stress cannot be laid upon the importance of this phase of the investigation and any appropriation reserved for its furtherance in the consideration of a powei scheme can be well and profitably applied. The more frequently these gaugings can be made the better, once a week at least, and for a period extending at least over one cycle of the water year.

Extract from Water Supply and Irrigation Paper No. 80, U. S. Geological Survey, by G. W. Rafter:

"The writer has found it very convenient to divide rainfall and run-off records into three periods, those of Storage, Growing and Replenishing, with a water year beginning December 1 and ending November 30. The storage period includes the months from December to May inclusive, during which the evaporation and absorption by plants is relatively slight, and a very large proportion of the rainfall appears in the streams.

"The growing period, June to August, inclusive, includes the period of active vegetation, when evaporation and absorption by plants is most notable. During this period frequently not more than 0.1 of the rainfall appears in the streams, and sometimes not more than 0.05 and even less. Ground water tends to become lower and lower during this period, unless the rainfall is much higher than the average.

"In the replenishing period, September to November inclusive, with the normal rainfall, ground water tends to recover, and the run-off is larger than in the preceding period. This period is replenishing in that there is a tendency to return to normal conditions."

Records thus obtained will furnish evidence in connection with two conditions of outstanding importance; namely, the minimum and the maximum flow. From the first, the minimum continuous power per foot of head can be deduced, while the second forms a basis for the design of permanent works and computations with reference to overflow and sluiceway discharge area. Also, these with the intermediate values of discharge, will make it possible to calculate the amount of the annual run-off without assuming a value for the run-off factor.

As to methods of discharge measurement, that of the current-meter only will be discussed, as, with proper management, this is the most accurate, satisfactory and generally applicable of all, and the following is based upon the assumption that a current-meter will be used.

The best time to locate a gauging station is during the period of low water, because a stretch of river that may have a very appreciable current at high stages may become a quiet pond during the low-water period. For this reason, it is well if possible to establish the gauging cross-section somewhere near the head of a flat rapid, above rough water, where there will be a measurable velocity at all stages of flow. Moreover, a cross-section like this usually has the advantage of being more or less permanent, as it will have a rocky or gravelly bottom which will not be materially affected by floods.

Having decided on the gauging section, the establishment of a gauge for recording water-levels is the next step. This gauge should be set with reference to a bench-mark well out of reach of flood-water, so that if the gauge is destroyed by flood or other means, it can be replaced without affecting the relation of subsequent readings to those taken from the old gauge.

Soundings may be most conveniently taken, on a river of moderate size, by means of a tagged rope or cable which may be permanently stretched across the stream, or else placed at the time of gauging, this point depending upon local conditions. The zero point of this rope or cable should always be set to a fixed point upon the shore above high water mark. In this way the individual soundings of every series will be taken over fixed points in the bed of the stream, these fixed points having their elevations established with reference to bench-mark mentioned above. From the data thus obtained it will be possible to plot a profile of the bed of the stream and as much of each bank as is necessary to bring the end elevations of the profile beyond the reach of flood-water.

This profile can be laid out to scale upon section paper and will prove valuable for computing discharge areas during periods of flood. Under ordinary conditions of discharge, soundings and velocity measurements can be obtained directly in the usual manner. In time of flood this is often impossible, but the water-level can easily be obtained with reference to the bench-mark and laid off upon the profile above described. From this the discharge area can be very closely estimated, assuming of course that the flood has caused no change of any account in the bed of the stream. At times when it is impossible to use the current-meter, surface velocities may be estimated by timing the passage of cakes of ice or floating debris over various portions of the discharge area. By using these in conjunction with the discharge area derived from the plotted cross-section, and applying the necessary velocity constants, a reasonable estimate of the flood discharge can be obtained.

The level-gauge should always be read upon the occasion of each gauging, and daily readings should be taken if possible. By plotting the gauge heights as abscissae and the corresponding discharges as ordinates, a discharge or "rating curve" is obtained, which is very useful in estimating discharge during extreme high water and for interpolating discharges to correspond to certain gauge-heights where opportunity for direct measurement has been lacking.

In connection with estimating annual run-off from discharge measurements, it should be noted that a value obtained in this way can only be termed an average one at best, and can be assumed as a minimum only if the annual precipitation for that particular year appears to be a minimum. An idea can be formed as to this by consulting the government records, if any exist, for the district in which the operations were carried on.

A reasonable indication of the run-off characteristics having been thus obtained, the question of artificial storage may be taken up as above described, provided the market demand makes such a course necessary.

Where more than one development location is available for any specific scheme, the question of choice of site opens up a wide field for discussion. From a hydraulic standpoint, the comparison would be based mainly upon available discharge and natural head, but if the scheme involves the generation and transmission of electric power, the location of the point of local distribution with reference to the sites of development introduces a new and important factor into the discussion, and it becomes largely a question of off-setting natural advantages against transmission distance.

Assume two sites upon the same stream having, as is often the case, approximately the same amount of water available, one site being adjacent to the point of electrical distribution and the other some distance away but having a considerably greater natural head.

As a general rule, the capital cost and annual charges for development will vary inversely with the head for the generation of a given amount of power; that is, the cost of a low head plant will be greater than that of a plant of the same capacity operating under a higher head, owing to the greater amount of water to be handled and the greater expense of low speed machinery. In the case under consideration, however, it is evident that the saving due to the development of the higher head must be offset against the capital investment and annual charges for transmission and transformation.

Here again the question of market requirement presents itself. Assume that the low head installation has sufficient capacity to meet the immediate demands of the market, and that, all things being considered, the comparative estimates place the balance to the credit of this plant as regards capital cost and fixed charges. Again, suppose twice this head is available at the other location. It is then evident that in the event of development, this plant, after meeting the market requirements, would have a reserve capacity equal to its already developed output, and the possible revenue to be derived from future market extension will be a measure of the value of this reserve power.

In the final analysis, therefore, the problem would resolve itself to this: Will the prospects of future market extension be such as to justify the additional capital expenditure and fixed charges, and the additional risk of service interruption, due to transmission and transformation?

It is to be understood that this is only one of an infinite number of cases that may be presented for solution, but the above will have served its purpose if it indicates in a general way the manner in which a hydraulic problem may be approached, and also the way in which the location, design and lay-out of a power plant may be influenced by the character and extent of the market.

In conclusion it may be said that on the part of the engineer, conservative judgment tempered with experience is very necessary, as the science of hydraulics, in so far at least as it deals with the phenomena of flow in natural channels, is based upon very approximate assumptions and is governed by obscure natural laws. For this reason an engineer may manipulate coefficients and constants in such a way as to involve very elaborate and impressive calculation, while an error in some fundamental assumption may discount his results to the point of absurdity. In the finer points of design, accuracy is of course essential, but in the preliminary studies it is a hundred times more important to be safe.

COPPER ANODES IN CHLORIDE SOLUTIONS

SAUL DUSHMAN

In the following paper I intend to give a summary of an investigation undertaken with the object of explaining the anomalous behavior of copper as anode in chloride solutions. Preliminary experiments showed that copper dissolved with a valency ranging from 1 to 2, according to the experimental conditions. It was observed that in concentrated hydrochloric acid solution, it dissolved as a univalent metal, while in more dilute solution the valency was greater, and finally attained a value of 2 for very dilute solutions. The particular concentration of hydrochloric acid at which the copper ceased to dissolve as purely univalent (i.e., cuprous) varied with the rate of stirring, rate of circulation, current density, and other factors. Increased stirring or circulation caused the metal to dissolve much more as cuprous, while increasing the current density, under otherwise constant conditions, increased the proportion of cupric.

Although several hypotheses could have been made to explain these experiments, the one chosen seems to be in best accord with the quantitative experiments described below. *It is assumed that the copper anode dissolves by the action of the curreut in such a manner that, at the boundary between solution and electrode, the chemical equilibrium between the cupric and cuprous salts in hydrochloric acid solution is maintained.*

The investigation therefore naturally divided itself into two parts: (a) Investigation of the chemical equilibrium, (b) determination of concentrations at the electrode in the electrolytic experiments. The chemical equilibrium between cuprous and cupric salts has been investigated by E. Abel,* R. Luther,** and Bodlander and Storbeck.*** A large number of experiments performed by myself, in which the methods of analysis and manipulation were different from any of the above, proved in conformity with those of the last named authors. The equilibrium between copper, cupric and cuprous salts in presence of hydrochloric acid is represented by two equations:

$$Cu + CuCl_2 \rightleftarrows 2\ CuCl \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$
$$CuCl + HCl \rightleftarrows HCuCl_2 \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

Cupric chloride dissolves metallic copper, according to (1), with the formation of a cuprous chloride. As well known, the latter is insoluble in water, but is soluble in hydrochloric acid solution, this fact being explained by the formation of the "complex salt" $HCuCl_2$, according to (2). Each of the above reactions is a reversible one; it ceases when there is attained in the solution a definite ratio between the products of the concentrations of the reacting substances on both sides of the equation. This last state is defined as an equilibrium. Assuming dissociation of the various salts taking part in the above reactions, the equations may be written thus:

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*E. Abel, Zeit. f. Anorg. Chem., 26, 361.

**R. Luther, Zeit. f. Physik. Chem. 36, 385.

***G. Bodlander and O. Storbeck, Zeit. f. Anorg. Chem., 31, 1, 458.

$$\overset{0}{\mathrm{Cu}} + \overset{++}{\mathrm{Cu}} \rightleftarrows 2\,\overset{+}{\mathrm{Cu}} \ \ldots\ldots\ldots\ldots \ (1a)$$

$$\overset{+}{\mathrm{Cu}} + 2\,\overline{\mathrm{Cl}} \rightleftarrows \mathrm{Cu}\overline{\mathrm{Cl}}_2 \ \ldots\ldots\ldots\ldots \ (2a)$$

According to the "Mass Law," when equilibrium is attained between copper, cupric and cuprous salts in hydrochloric acid solution, we must have the following relations:

$$\frac{\left(\overset{++}{\mathrm{Cu}}\right)}{\left(\overset{+}{\mathrm{Cu}}\right)^2} = k_1 \ \ldots\ldots\ldots\ldots \ (1b)$$

$$\frac{\left(\mathrm{Cu}\,\overline{\mathrm{Cl}}_2\right)}{\left(\overset{+}{\mathrm{Cu}}\right)\left(\overline{\mathrm{Cl}}\right)^2} = k_2 \ \ldots\ldots \ (2b)$$

where the symbols in brackets denote the concentrations of the particular ions. Bodlander and Storbeck determined the values of the constants k_1 and k_2 to be 1.4×10^4 and 4×10^4 respectively, concentrations being taken in mols (formula-weights) per litre.

The second part of the investigation had for its object the determination of the concentration at the anode during the electrolytic experiments, so that the values of k_1 and k_2 might be calculated from these and compared with those obtained from the equilibrium experiment. Fig. 1 is a diagram of the electrolytic cell used. It consisted of two porous cylinders, P_1 and P_2, between the ebonite discs, *E E*, two concentric glass cylinders, *L* and *M*, also held between ebonite discs, and a rotating copper anode, *A*, making contact with a shaft and holder, *H*. To prevent liquid from entering within the anode tube, two ebonite plugs (the lower of these having a glass tip, *T*) were provided with threaded holes, so that they could be tightened against the copper, as shown in the diagram. The tube could therefore be taken off the plugs and weighed. Its area was about 40 square centimetres. A rubber tube, with stopper, *S*, fitted over the upper plug. The electrolyte entering *B* passed between the two porous cylinders, through holes in the center disc, *E*, and the glass cylinder, *M*, and up and around the anode, leaving by means of the exit tube, *D*. The cathode consisted of a platinum gauze, *C*, attached around the discs *E*. The different parts were cemented together. Cork wedges between the discs and the glass container, *F*, prevented any lateral motion of the discs when the anode was set rotating.

Since hydrochloric acid containing air in solution dissolves copper even without current, the solution to be electrolyzed was always freed from air by exhaustion, and then saturated with carbon dioxide. Blank experiments showed that in such a solution the copper dissolved only very slightly. A large bottle filled with stock solution was permanently connected with a carbon dioxide generator, and as the solution ran out into the cell, the gas took its place. After circulating through a cell once, the electrolyte passed into a measuring cylinder, and was then discarded. A copper coulometer and ammeter were placed in series with the cell. During the experiment, the rates of circulation and stirring were kept nearly constant, the average speed of rotation being about 1,500 per minute in all the experiments.

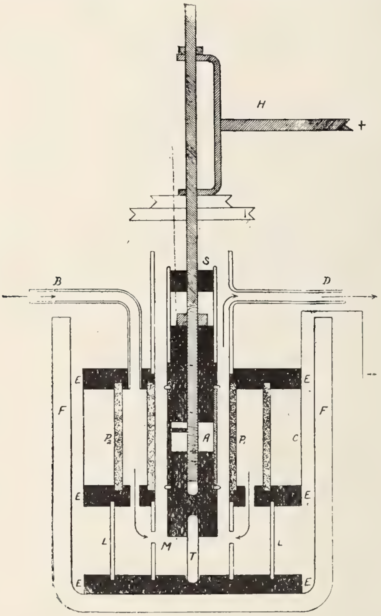

Fig. 1

The anode tube was weighed before and after electrolysis and the loss compared with the gain at the cathode of the coulometer. By means of the measuring cylinder the total volume of solution, V ccm, passed through the cell during the electrolysis, was also determined.

It has been mentioned above that copper dissolved in these solutions with a valency ranging from 1 to 2; that is the ratio of anode loss to coulometer gain varied from 2 to 1. Denoting this ratio by $1 + a$, it is evident that for every 96540 coulombs, $(1-a)/2$ formula-weights cupric salt ($CuCl_2$) and a formula-weights cuprous salt ($CuCl$) would enter the solution. Hence the average concentrations in the solution, during the electrolysis, would be $(1-a)/2V$ and a/V, in formula-weights (or *mol*s) per ccm. That, however, these would not be the same as the concentrations just at the electrode surface, is evident from the following:

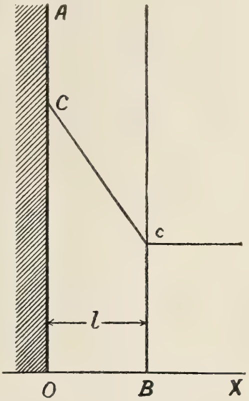

Fig. 2

In Fig. 2, let *OA* represent a section of the electrode, whose area is *S*. Let *OX* represent the distance from the electrode. It has been shown by Nernst and Brunner that in a rapidly stirred solution the diffusion is limited to a very thin layer close to the electrode, the thickness *L* decreasing with increasing rate of rotation. Outside this layer, the solution is of uniform composition. The concentration of $\overset{++}{\mathrm{Cu}}$, for example, at the electrode and in the solution are represented by *O C* and *B c*, respectively. Owing to the circulation of the electrolyte, the concentration in the solution rapidly attains the constant value *B c*, and the distribution of concentrations in the layer is given by the line *C c*. Now since all the concentrations remain constant during the electrolysis, it is evident that the following relation exists between *O C* and *B c*:

The amount of cupric ion entering the layer in any time is equal to the amount diffusing out into the solution, together with the amount transported in the same time, or

$$\frac{(1—a)\,i\,t}{2 \text{ x } 96540} = \frac{D_f\,S\,t\,(C—c)}{L} + \frac{(1—a)\,n\,i\,t}{2 \text{ x } 96540}$$

where i = current in amperes,
t = time in seconds,
D_1 = diffusion constant in cms/sec.,
n = transport number of ion in the solution.

Since $c = (1—a)it/\,(2 \times 96540\,V)$ where V = volume in cc., as shown above,

$$C = \frac{(1—a)\,i\,t}{2 \times 96540}\left(\frac{1}{V} + \frac{L\,(1—n}{D_1\,S\,t}\right)$$

It will also be observed that the concentration of $\overset{++}{\mathrm{Cu}}$ in the solution was assumed to be the same as that of CuCl_2. The cuprous salt was, however, present in the solution as $\overset{+}{\mathrm{Cu}}$ and $\overline{\mathrm{CuCl}_2}$, the ratio between these being determined by the value of the concentration of $\overline{\mathrm{Cl}}$, according to equation (2b) above. Denoting by b, the fraction of cuprous salt present at CuCl_2, and remembering that the average concentration of cuprous salt in the solution would be ait/96540 V, it is evident that

$$C^1 = \frac{abit}{96540}\left(\frac{1}{V} + \frac{L\,(1-m)}{D_2\ S\ t}\right) \ldots\ldots\ \ldots\ldots (4)$$

where C^1 = concentration of $CuCl_2$ at anode surface

D_2 = diffusion constant of $CuCl_2$ in cms/sec.
m = transport number of ion in the solution,
while the other letters denote the same quantities as in (3).

Since the equilibrium (2a) must hold at the anode surface as at every other point in the solution, it follows from (2b) that

$$\left(\overset{+}{\mathrm{Cu}}\right) \text{ at the anode, } = \frac{C^1}{k_2(\mathrm{Cl})^2} \ldots\ldots\ldots\ldots (5)$$

Having obtained in this manner the concentration of $\overset{+}{\mathrm{Cu}}$ at the anode, it remained to calculate the value of k_1 according to (1b), by making use of equations (3) and (5).

The values of D_1, D_2 were calculated from the mobilities according to the formulae of Nernst, Abegg and Bose; while the value of L was determined experimentally by a separate set of measurements. The thickness of the layer in which diffusion took place was found to be about 25×10^{-4} cms, with the rate of rotation used in this investigation. The fall in concentration in this layer was found to be very great. Thus, in one experiment with N/200 HCl, the concentration of $\overset{++}{\mathrm{Cu}}$ at the anode was 0.8×10^{-3} while in the solution it was 0.5×10^{-3}.

The concentrations of HCl and $CuCl_2$, rate of circulation and current, were varied in different experiments, and after calculating the concentrations of $\overset{++}{\mathrm{Cu}}$ and $\overset{+}{\mathrm{Cu}}$ at the anode surface, the values of k_1 were determined according to (1b).

With constant rate of circulation, the value of k_1 was found to be constant, and independent of concentrations of HCl and $CuCl_2$, as well as of the current. But with increased rate of circulation the value of k_1 increased also, varying from about 0.5×10^4 for low rates to 2×10^4 for extremely rapid circulation. It was only after a great many experiments had been performed, and apparently useless results had been reconsidered from this basis of rate of circulation during the electrolysis, that this conclusion became evident.

But why should k_1 vary with rate of circulation? Our initial assumption does not allow for any such variation: k_1 should be a constant under all conditions. The only practical explanation seems to be increased oxidation of cuprous salt in the solution as the rate of circulation decreased. For suppose that in those experiments where the circulation was very slow, the cuprous salt in the solution became oxidized; then the calculated value of $(\overset{+}{\mathrm{Cu}})$ would be too high, while that of $(\overset{++}{\mathrm{Cu}})$ would be too low, and hence k_1 also too low. On the other hand, with very rapid rate of circulation, there would not be any time for the $\overset{+}{\mathrm{Cu}}$ to be oxidized while in the cell, and hence the calculated would approach more and more nearly the actual values as the rate of circulation increased; that is, k_1 would become more and more nearly equal to the correct value.

It will probably be possible to test this assumption by electromotive force determinations of the ratio of the concentrations of $(\overset{++}{\mathrm{Cu}})$ and $(\overset{+}{\mathrm{Cu}})$ in the circulated electrolyte. All I can state is that qualitatively the experiments fit in with the above oxidation theory; whether there is also quantitative agreement remains to be determined by the further work in which I am at present engaged.

THE DESIGN OF CANAL DIVERSION WEIRS ON A SAND FOUNDATION.

W. G. BLIGH, M. Inst C.E.*

Sand is proverbially an unsuitable material on which to found a solid structure of any kind, but, when this structure in addition acts as a dam in holding up water, nine persons out of ten would consider that its stability under such circumstances was absolutely impossible.

Such, however, is by no means the case, and the object of this paper is to show the means adopted to insure the safety of structures such as river weirs, which are not only exposed to undermining by their foundation being washed out by subsoil percolation, but are also subject to the erosive action of the powerful current of a river in flood, which completely submerges the whole work. Not having its base resting on solid impervious material as clay or rock, the masonry of which the weir is composed is further subjected to the disability of loss of weight by displacement, which often amounts to one half of its weight in air.

When a dam of earth, as a reservoir embankment, is thrown across the sandy bed of a stream, leakage will necessarily take place beneath the base of the dam. With a low level of water in the reservoir this leakage may be quite harmless, that is to say, the percolating water will not carry with it any particles of sand; when, however, the depth of the water in the reservoir, that is, the head acting on the base, is increased, the percolating undercurrent will likewise increase in volume and velocity and will eventually convey particles of sand along with it and so gradually undermine the dam.

The weight of the dam is naturally the same whatever be the depth of water impounded, and further, sand is practically incompressible, consequently the imposed load must be ruled out

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Extracts from an address delivered before the Engineering Society, Oct. 14th, 1908.

as a determining factor in this case. The real factor influencing the safety of the work is the length of the enforced percolation, or as it is technically termed the creep of the undercurrent, which is clearly identical with the base width of the earthen dam. This length of percolation must naturally be some multiple of the head of water acting on the work, and if we can only find out a safe value for this multiplying co-efficient, suitable to the particular sand under consideration, we shall be enabled to design any structure on a sand foundation with perfect confidence as regards its safety with reference to statical considerations.

An example of the successful construction of a dam on a sand foundation is that of the Amani Shah storage reservoir at Jeypore in India. This dam upholds a depth of over 30 ft. of water. It is built of sand and is founded on pure sand, but its base width is exceptionally great, being over 350 ft., i.e., 12 times the head. The silting up of the river bed, which occurred before the full flood level was reached, increased the effective value of the length of creep by over 100 feet, and thus enabled the work to stand an increased head of 44 feet in perfect safely. This dam is not water tight, and does not pretend to be so, but the visible leakage is unimportant.

The natural question will arise, if this is the case, why are the foundations of bridges over rivers, reservoirs, dams, etc., always carried down to solid rock or clay? The answer is that in these cases it is cheaper to do so. As we shall see later, the correct value of the requisite base width will be from 10 to 20 times the head, consequently in case of a dam 60 ft. high founded on sand, a base width of say 15×60=900 feet would be necessary for safety. Thus it would, as a rule, be more economical to adopt a deep foundation. As regards a river bridge, isolated piers of great depth are generally the only practicable and economical method of construction.

In large rivers the bed of sand is often of great depth, the piers of the Benares Railway Bridge over the Ganges River had to be sunk over a hundred and fifty feet through the sand before clay was met with; consequently, for a continuous work, like a river weir, a deep foundation is an economic impossibility.

The definition of the term weir, in contradistinction to that of dam, implies that the river water falls over its crest, whereas in the case of a dam the surplus flood water is conveyed either through the body of the work, as in the case of the Assuan Dam in Egypt, or else its escape is provided for by a specially built waste weir distinct from the dam itself. Weirs built across rivers, with sand beds of great depth, are invariably what are termed "diversion" weirs, that is to say, their function does not include that of the storage of water, but is limited to the diversion of a portion of the discharge of the river down a canal through an intake; a good example of this is the Calgary canal head in Alberta.

The function of a weir is to raise the water of the river when the latter is at a low level, in order to pass a sufficient supply down the canal. During flood time, or whenever the supply exceeds the demand, the crest is topped and the surplus water follows its course down the river. Owing to the sandy nature of the bed, which in part is carried along in suspension during floods, deposit takes place in rear of the weir almost to crest level, and in some cases even higher, so that during low water there is but a narrow channel from which supply can be drawn. This channel is artificially conserved by the adoption of weir scouring sluices in close proximity to the canal intake. As canals, when on sand, mostly take off at not more than 2 to 5 feet above river bed level, and their full supply depth seldom, if ever, exceeds 10 feet, it is clear that the height of these submerged diversion weirs will not be greater than 15 feet, the general average being 10 or 12 feet. On boulder or clay formations much greater heights are practicable.

A dam is subjected solely to hydrostatic pressure, but a weir on the other hand has also to withstand the dynamic scouring action of water. The design, however, is mainly influenced by hydrostatic considerations, for which alone precise rules can be framed, with, however, this proviso that the design of the work must also suit what may be termed the hydrodynamical side of the question.

The following facts may here be noted:—

The hydrostatic pressure on a weir is greatest when the head water stands exactly at crest level, the river bed being empty below; when this occurs the hydrodynamical forces are nil.

Again, when the latter forces are a maximum, *i.e.*, during full flood, the hydrostatical pressure on the weir foundation is at a minimum.

The hydrostatic problem, with water at rest, will first be considered as follows:—

Figure 1 represents a pipe line BC, proceeding from the bottom of a reservoir of water. The original head *H* is the

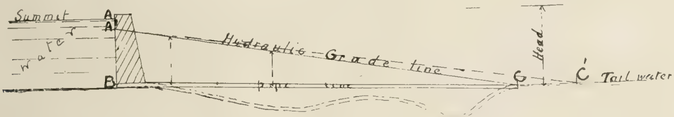

FIG 1

difference of levels between A, the summit level, and C, the tail water, it being presumed that the outlet at C is free and unrestricted. The line A_1 C drawn from a point near the summit level to C, is termed the hydraulic gradient, or grade line, and the hydrostatic pressures on the pipe at any point are measured by vertical ordinates drawn up to this line. The distance AA′ is the head due to the uniform velocity of the current in the pipe plus a further small quantity representing loss of head at entry.

Fig. 2 represents a simple section for a low masonry weir, built on river sand, supposed, as is usually the case, to be completely submerged during floods. Such a work must necessarily consist of a vertical wall of masonry, or any other material, whose function is to uphold the water, connected with which, is a horizontal apron of some description, for protection against erosion of the river bed by falling water. In this particular case an impervious masonry floor is provided. The base of this floor C D, rests on a stratum of pure sand. The vertical wall holds water up to the summit level H, the tail level, *i.e.*, the original low water level of the river, is supposed to be at B, *i.e.*, coincident with the floor surface. The head *H* is the difference of level between the summit and tail levels, which is a maximum when the reservoir level is flush with the weir crest. The reason for this is that when the water overtops the crest the velocity of the film passing over exceeds that of the tail water in the normal channel below, consequently the rise of the tail water will be more rapid than that of the head water—the ratio being from 2 or 3 to 1, varying mainly with the slope of the river bed. The action of the impounded water in its endeavor to reach its own level, a property inherent in liquids, is to force a passage through the sand stratum underneath the impervious floor, the particles of liquid taking a curved course, first downwards then horizontally, and once the obstructing plane is passed, upwards.

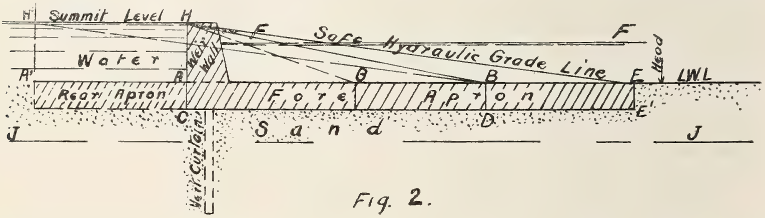

Fig. 2.

The proposition here presented is exactly similar to that in Fig. 1, the only difference being that instead of the water being confined in a pipe of a limited size, it is confined within the sand substratum, being prevented from rising above it. The theoretical velocity due to the head of water, is reduced in the pipe by friction against its sides to a smaller constant velocity right through; in exactly the same way, reduction, or neutralization of head is effected by friction in the passage of water between the particles of the sand. The greater the length of the confined passage, the less will be the velocity of the slowly percolating stream.

It is evident that under similar conditions of head and base length, the velocity of the current in different weir beds must vary with the nature of the sand stratum in accordance with its qualities of fineness or coarseness. Fine sand will be closer in texture, passing less water at a given head than a coarser variety, at the same time fine sand will be disintegrated and washed out under a less pressure. The problem now to be solved is evidently what proportion the base CD, or l, should hold to the head H in order to insure safety from washing out or from what is technically termed "piping." This value can only be obtained experimentally, that is, by deduction from sections of existing successful river weirs. Fortunately there are also some most instructive examples of failures due to insufficient length of base, so that the safe value of the relation of l to H can be deduced with absolute certainty.

In Fig. 2, supposing the length of the base CD or l, of the floor (which clearly must be some multiple of H) provides a length of creep or percolation sufficient to reduce the head, or, strictly speaking, the velocity of the current, to such proportions, as will just prevent piping. Then the hypothenuse HB will represent the hydraulic gradient. This slope starts from the summit level itself, for this reason, that the velocity head is insignificant and the loss at entry is nil. This gradient is found to be about 1 in 10 for fine sands and 1 in 8 for coarse sands, and might be termed the equilibrium gradient. Now the water having free egress at the point D, the conditions are identical with those in Fig. 1, and the upward head of water, acting on the base of the floor CD will be correctly represented by the vertical ordinates of the figure HCDB, and the total pressure by the area HCDB.

In this discussion the symbol W, commonly employed to represent the unit weight of water, *i.e.* the weight of one cubic foot, approximately 62.5 pounds, is invariably omitted. Where weight comes under consideration it is represented by Volume Specific Gravity, or by $V\rho$, the Greek letter ρ being used to indicate Specific Gravity, being preferred to the letter G sometimes employed for the same purpose, since the latter may possibly be confounded with the recognized symbol denoting Gravity. In the same way, the pressure of water is represented by H, the head, it being actually of course HW.

With regard to the value to be assigned to l, in actual construction a considerable factor of safety is necessary, so that the safe value of l must be half as much again as its bare value. If the floor be thus increased in length to the point E, so that CE=1½ CD, the safe hydraulic gradient will be HE, and the value of c in the expression $l=cH$ will become 15. This lengthening of the floor will, however, have the effect of increasing the upward pressure on it in proportion as the ordinates of HCE′E are greater than the ordinates of HCDB, consequently there is a positive disadvantage in lengthening the impervious floor beyond what is necessary to insure an absolutely safe base length, *i.e.*, one sufficient to prevent disintegration of the sand substratum by piping.

Supposing the length of floor reduced below the minimum CD, to CG, the hydraulic gradient then will be HG. The ordinates of the pressure figure are less than in either of the preceding cases, but failure will take place by piping, the floor becoming gradually undermined, by the sand being slowly washed out, the reduction of the velocity effected by friction in this shorter length being insufficient to overcome the disintegrating horizontal influences of the current of water. Two such cases have actually occurred in the case of the Chenab and the Jhelum weirs.

It is self-evident that the effective weight of the floor must equal or exceed that of the upward hydrostatic pressure unless its construction is such as to render it capable of resistance to bending stress. In the case of Narora weir a floor of insufficient weight has been known to stand for several years, but eventually, owing to a comparatively small increase in the upward pressure, it blew up. Weight in the floor and superstructure generally, well in excess of the hydrostatic pressure, is always a desideratum, and is only limited by considerations of economy.

We have already seen that the proportion of $l : H$ or the value of c, the expression $l = cH$ varies in different rivers. River sands will be classified according to the following known qualities.

Class 1a—The Nile River sands. Coefficient adopted 18.

Class 1—Fine light micaceous sands such as are found in rivers taking their source in the Himalayas, including the Ganges, Jumna, Indus, and the four main Punjab rivers; to this class belong also the sands of the Colorado River. Coefficient adopted 15.

Class 2—The coarse-grained sands of the rivers of Central India, Madras and Bengal; most river sands belong to this class. Coefficient adopted 12.

Class 3—Boulder and sand formation. Coefficient adopted 6 to 9.

The coefficients are all obtained from actual examples.

With regard to hydrostatic pressure on the base the following points require notice.

In Fig. 2, if a hole were bored in the floor CE′ and a pipe inserted, the water would rise up as far as the existing hydraulic gradient HE. The head acting on the base CE′ at that point would thus be represented by the ordinate of the figure HCE′E, and not of the triangle HAE. That is, to what may be termed the external head is added that due to displacement. To avoid confusion, the extraneous head of water symbolized by H, which always means the difference of levels above and below a weir or regulator, will be kept distinct from that due to displacement or immersion, this latter pressure being allowed for by reduction in the effective weight of the immersed body. As is well known a solid material immersed in water loses effective or sensible weight corresponding to the weight of water displaced. Thus a body whose specific gravity is ρ has a weight in air of $V\rho \times 62.5$ pounds, if V be its volume in cubic feet, but when immersed in water its effective weight is $V(\rho-1) \times 62.5$ pounds.

In the figure when the low water level is at E the floor ACEE′ is clearly just immersed, and the upward pressure due to displacement will be equivalent to the weight of water displaced. When the tail water is at some higher level, as at FF, the status as regards upward pressure due to displacement is in no way altered, the increase of upward pressure below the slab, due to the greater depth of immersion, being compensated for by a similar increase in the downward pressure upon the top of the slab.

When the tail water is at the level CDE′, the weight of the floor is clearly unimpaired by flotation, when intermediate, the effective weight of that portion of the floor lying below the level has alone to be considered as thus impaired.

When the floor is built well above LWL, as when the LWL is at JJ, the sand substratum being porous, the water level will rise up to the base of the impervious floor thus practically reducing the head from HJ to HC. The acting head therefore cannot be taken as extending below the actual impervious base of the weir, except as regards calculation for base length, or length of creep.

In Fig. 2 it is evident that the value of l is in no way affected, whatever be the position of the vertical drop wall with regard to the horizontal floor. For instance suppose the floor extended backwards to A′ and AA′ made = BE, then the action of the head of water is thrown back from H to H′ the hydraulic gradient will be H′B parallel to HE, and the statical condition is in no way altered.

This rear projection is termed the rear apron. Its value in design has only recently been recognized. The upward pressure acting beneath the rear apron will be simply that due to displacement, and as the value of ρ for the materials employed in the construction of the apron is greater than unity, this upward pressure due to flotation is more than counterbalanced by the downward pressure due to the weight of the floor. As the rear apron is in addition free from the erosive action of falling water, it can be constructed of less expensive material than the fore apron or floor. On the other hand it must be impervious and must have a water-tight connection with the weir wall, otherwise the head may act between it and the weir wall, thus practically isolating it from the rest of the work. This actually occurred in the case of Narora weir. Another weir, the Chenab, failed by sinkage of the floor, the sand base having been gradually washed out by the undercurrent.

Theoretically, the rear apron would be effective if only a thin impervious layer, but practically it is considered that unless constructed of a definite weight, water passing underneath it would partake of the nature of a surface current and so the apron would not be effective in the neutralization of head.

With weirs of ordinary height, with a sand coefficient of 12 to 15, and with a value of H up to 15 feet the economical length of the rear apron will not exceed 3 to 5 H. The reason being that the rear apron performs but one function, namely, statical, whereas the fore apron in addition to this, acts as an anti-erosive shield; consequently material placed in front of the drop wall is of greater value than that in rear, and if the rear apron is designed too long there will necessarily be excess material in the whole section, which by a more economical distribution could be avoided. The reason for this is that dynamical considerations cannot be lost sight of and the requirements to meet this second governing condition demand a certain minimum length of fore apron symbolised by L which is measured from the toe of the drop wall. This length consists in part of the masonry floor designed to meet the requisite length of creep, i.e., for statical requirements, and when this length falls short of the minimum the balance has to be made up by loose stone rip rap as a further protective covering to the sand. This latter portion is termed the talus.

The value of L is influenced by the erosive power of the current, which again is dependent on the proportional obstruction afforded by the weir, i.e., the height of the masonry crest combined with the shape of its profile, and the velocity of approach at flood times. These several considerations will determine the designer as to what value will be suitable for adoption, having due regard to precedent.

For direct overfalls with floor at LWL the value of L may be taken as from 15 to 20 H for class 1, and 12 to 16 H for weirs of class 2, H in this case not being necessarily the maximum statical head but the height of the permanent masonry weir crest above floor level.

The summit level in all modern weirs is raised by means of collapsible crest shutters, which fall automatically in flood times, to a height varying from 2 to 6 feet above the solid masonry weir crest. This device lessens the permanent obstruction to the normal river waterway.

We have hitherto been considering only a section which has no vertical depressions in the base line. The creep of water beneath an impervious apron is known to hug all vertical sinuosities. Thus if a row of sheet piling or some other impervious curtain were inserted below the base CE in Fig. 2, the line of creep would be forced down one side of the vertical obstruction and up the other. This added length of creep is thus twice the depth of the curtain. The insertion of sheet piling or other form of curtain-walling is thus a most valuable means of increasing the length of creep and thus saving length in the expensive horizontal apron.

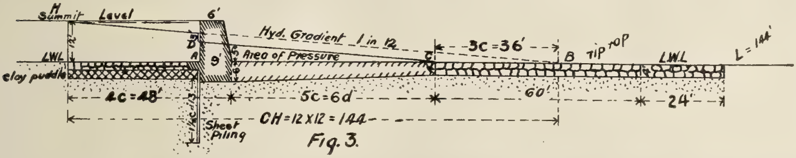

Fig. 3.

An example of the method of applying the principles already enunciated will now be given for the design of a weir under assumed conditions, viz. :—

$H=12$ feet.

River, Class 2 with $c=12$. Whence $l = c \times H = 12 \times 12 = 144$ feet.

The first point to be decided is the length to be given to the rear apron, and the depth of the sheet piling, as it is proposed to adopt a curtain below the weir wall. The thickness of the fore apron at the toe of the drop wall, which is the crucial point in the whole design, is determined by the values thus adopted, for this reason, that the unbalanced hydrostatic upward pressure is here first felt and the neutralization of head up to this point should be sufficient to reduce the required depth of floor to reasonable and economical dimensions. The minimum average thickness of the fore apron is obtained by the empirical formula $T = \sqrt{\frac{3h}{2}} + 1\frac{1}{2}$ where h = height of solid masonry weir in feet and T = thickness of fore apron in feet. In this case $T = \sqrt{18} + 1\frac{1}{2} = 5\frac{1}{2}$ feet nearly.

In designing these weirs it is a great convenience to make all dimensions multiples of the coefficient c, as then each unit represents a neutralization of one foot of the original head. The length of the rear apron should be measured back from the toe of the drop wall. In the design this length is made $= 4c = 48$ feet. Deducting the base thickness of the weir wall, which is 9 feet, the actual length of the rear apron is about $3c$ feet. This, if anything, is somewhat short, a length of $3\frac{1}{2}c$ feet would give better results. The thickness of the rear apron, composed of puddle covered with stone rip rap, will be 5 feet, it cannot be less.

Now we come to the sheet piling, steel or concrete steel. This is made $1\frac{1}{2}c$ or 18 feet in depth, consequently the total neutralization of head effected up to the toe of the weir wall is $(4 + 3)$ ft. $= 7$ feet, leaving 5 feet hydrostatic pressure head acting here. The value of ρ for the material in the masonry fore apron will be taken as 2 (a common low value). The apron is submerged, lying below L.W.L., its effective weight will therefore correspond to (ρ—1). Now, as the effective weight of the floor should (it is deemed) exceed the upward pressure by at least one-fifth, as a precautionary measure, with a hydrostatic pressure due to 5 feet of head the necessary thickness of masonry with an effective weight corresponding to (ρ—1) will be 5 + 1 or 6 feet. The length of the fore apron will be the remaining balance of cH, or $(12—7)c = 5c$ or 60 ft., and the terminal thickness, theoretically nil, is made 4 ft. for other than statical reasons. This ends the design as regards statical requirements. For anti-erosive purposes the floor will have to be continued as a talus of loose stone pitching for another 84 feet, giving a length, measured from toe of drop wall, of $12H = 144$ feet. This, as we have seen, is obtained from an empirical rule, and can be varied as experience may dictate. The minimum length of fore apron is 4 to $5H$.

The graphical method of design is shown on the same figure and is very simple. From the extremity of the rear apron the total requisite base length, $= cH = 12 \times 12 = 144$ feet is set out to the point B. The line HB then is the hydraulic gradient of 1 in 12. From B set back BC = vertical portion of the base length $= 3c$ or 36 feet, and from the point C draw a line CD parallel to HB up to D, its intersection with a continuation of the vertical curtain.

The triangle DAC is the triangle of pressure.

The thickness of the drop wall at its base is found by the following formula: $\frac{H'}{\sqrt{\rho}}$ in which H′ is the height above floor of the head water at the time when the tail water is level with the crest, being generally 1½ times the height of the solid drop wall. But when the maximum statical head, *i.e.*, to shutter crest exceeds this, H' will become H and the formula $\frac{H}{\sqrt{\rho}}$

We will now give another example of design of a direct overfall weir with floor at LWL, viz., that of an alternative design for the Chenab weir. The actual given conditions are:—

$H = 13$ $c = 15$. Whence l must $= 13 \times 15 = 195$ feet.

In this design the original arrangement is followed of having the permanent drop wall of low elevation, the requisite summit level being obtained by the use of steel collapsible crest shutters As in the existing work, the level of the crest of the drop wall is placed at seven feet above extreme low water, while the remaining 6 feet required to bring the summit level to RL 728 is provided by the shutters. (See Figure 4.)

The commencement of the rear apron is placed $4c = 60$ feet behind the toe of the weir wall, below which sheet piling $1c$ or 15 feet in depth is provided. These neutralize 6 feet of head leaving a balance of 13—6 = 7 feet, hence a farther base length of 7 × 15 = 105 has to be provided in the fore apron. This is too long for actual requirements, which are 5 H = 65 feet, consequently another row of sheet piling is introduced at the end of the floor with a depth of ½c = 7½ feet. This admits of the curtailment of the floor by c or by 15 feet, reducing it to 6c or 90 feet. There are thus two vertical depressions in the base line.

The graphical diagram is shown in figure 4A. First, the total required base length or 15H = 15 × 13 = 195 feet is measured off from the commencement of the rear apron, and the hypothenuse is drawn in from the point thus obtained. Secondly, the respective values of the two vertical depressions are set back, viz., 2c = 30 feet, and c = 15 feet. A line parallel to the hydraulic gradient is then drawn from the first-mentioned point up to its intersection with a vertical through the first row of piling. A second parallel cannot be drawn from the second point as the intersection with the vertical is at the same spot, consequently the second step occurs at this very point. The outline of the pressure area below the weir wall is not a triangle, as heretofore, but a trapezium. The value of ρ is here 2¼; the thickness of floor necessary to counterbalance by its weight the hydrostatic pressure will thus be about 6 feet. (See figure.) This thickness is hardly sufficient and should be increased to 7 feet at least.

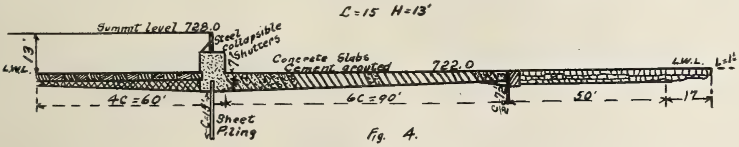

Fig. 4.

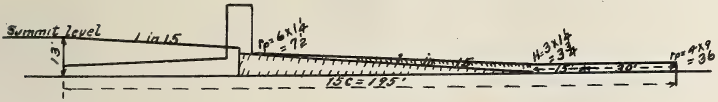

Fig. 4A

The rear apron is composed of puddle overlaid with concrete slabs, the weir wall is of concrete, the fore apron is of concrete slabs laid on a slope, breaking joint, subsequently cement grouted. This is a novel but economical method of subaqueous construction, and was first adopted at the Colombo breakwater.

This design would, (it is now considered), be improved by increasing the length of the rear apron from 4c to 5c, and correspondingly reducing the fore apron to 5c or 75 feet, the thickness could then remain as it is in the drawing. This example is useful as showing the ease with which the design can be altered by manipulation of the length of the rear apron and depth of rear curtain, till the most economical arrangement is arrived at.

THE NEW THERMODYNAMIC AND HYDRAULIC LABORATORIES OF THE UNIVERSITY OF TORONTO

ROBT. W. ANGUS, B. A.Sc.
Professor of Mechanical Engineering

During the past years the growth of the Faculty of Applied Science and Engineering has been very rapid indeed, and as is common in such cases, the increase in accommodation has not kept pace with the increase in the attendance. On this account the buildings have been overcrowded in every way and the consequent pressure has become very great.

This pressure has been felt very greatly in the Thermodynamic and Hydraulic laboratories, where, partly on account of the somewhat rapid development of steam and gas plants and the desire on the part of Canadians to develop their water-powers, and partly because of the growth of the Faculty, the attendance has increased rapidly from year to year. To meet the increased demands new apparatus has from time to time been installed until the available space has been used up, and the crowding has caused complications to arise between the two laboratories, making the work difficult. It has also been impossible to give any work in these laboratories to the Third Year students, so that they have been unable to follow up the lecture work with experiments which would illustrate the points brought out. To overcome these defects the new laboratories are being built.

The new building, known on the architect's plans as the Thermodynamics Building, contains a Thermodynamic laboratory, an Hydraulic laboratory, a boiler room, some private rooms for the staff and study and work rooms for the students.

The building faces the west and the front part of it, only a portion of which is now being erected, will contain in the basement students' rooms and a machine-shop, and on the upper floors the offices and study rooms connected with the work. This section of the building is the only part not now being completed.

On the south side of the building is the Thermodynamic laboratory, one storey high, covering a space 155 feet by 60 feet, the light all being obtained from the roof. This laboratory, which is high and airy, is divided into two parts, one of which is 40 feet wide and runs the full length of the building. In this part all the steam and gas engines will be installed as well as some other machines, and the whole area will be served by a travelling crane 40 feet long running from end to end of the building. This section is to contain a triple-expansion engine, simple and compound engines of various types, an air compressor, steam turbines, apparatus for testing injectors, indicators, etc., gas and oil engines of various types and other apparatus of similar nature. Most of this apparatus will be put in as soon as the building is completed. The other part of the laboratory, which is 20 feet by 155 feet, is partly taken up by the goods entrance but mainly by small laboratory rooms about 15 feet by 20 feet each. It is intended to equip these rooms with such apparatus as a refrigerating machine, air brake apparatus, a suction gas plant, valve setting engines, apparatus for testing the value of lubricants, etc., and they are so arranged that they will accommodate a small number of students who will be able to carry out experiments and be comparatively free from the noise and steam of the main part of the laboratory. These rooms have brick walls on three sides and open off the main steam laboratory by means of doors in a glass partition.

To the east of the Thermodynamic laboratory and at the back of the building is the boiler room, 45 feet by 70 feet, which is also lighted from the roof. This room will contain four boilers, three of which are now being installed and which are capable of running at a pressure of 200 pounds per square inch. One of the boilers is also arranged with a superheater. These boilers will be so piped up to the engines that complete engine and boiler tests may be made. The room also contains two chimneys specially arranged for the study of problems connected with chimney draft and capacity, and the necessary pumps and other apparatus. The boilers in this room are exclusively arranged for experimental work and are not used for regular service work.

The Hydraulic laboratory occupies the northern side of the building and this part contains three floors, the lower two of which are for the hydraulic laboratory and the upper one for study rooms. Each of the floors of the hydraulic laboratory is 40 feet by 112 feet, the distance between floors being 18 feet and 15 feet respectively, so that the rooms will be well ventilated and give good head room. This laboratory is lighted from the north and east sides by large windows running through the two storeys which occupy about three-fourths of the entire wall space.

The main or upper floor of the Hydraulic laboratory will contain a large weir tank capable of measuring six cubic feet per second, reaction turbines, impulse turbines and necessary tanks, orifice and weir tanks, various water meters, centrifugal pumps, apparatus for measuring the friction of water in pipes and hose, apparatus for the use of Pitot tubes, etc. A large pressure tank running through the two floors and up into the roof discharges into the large weir tank.

The lower floor is largely occupied by the measuring tanks and the pumps and engine for driving the latter. The pumps are high-lift turbine pumps specially arranged to give great flexibility for the purpose of laboratory work. In addition to the above there will be an open trough 5 feet wide, 4 feet deep and running the full length of the building, with a weir at the end, in which experiments on current meters and other apparatus may be made.

In designing the laboratories, care has been taken to provide for proper light and air, to arrange for the convenient handling of all apparatus, and to accommodate comparatively large classes of students. With this in view the arrangement will permit of the use of almost every piece of apparatus in the building at the same time and without interference of the experiments one with another. An endeavor has also been made so to arrange the apparatus that pieces especially adapted for research work may be continuously available in order that the work may be well carried out.

At a later date a more complete description with plans and drawings will be given.